UNITED STATES DEPARTMENT OF THE INTERIOR, Fred A. Seaton, *Secretary*

FISH AND WILDLIFE SERVICE

LARVAL FORMS OF THE FRESH-WATER MULLET (*Agonostomus monticola*) FROM THE OPEN OCEAN OFF THE BAHAMAS AND SOUTH ATLANTIC COAST OF THE UNITED STATES

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ABSTRACT

Ten larval specimens of the fresh-water mullet (*Agonostomus monticola*) were captured in the open ocean off the Bahamas and South Atlantic Coast of the United States. This is the first record of this species from the open ocean. These larvae are described and illustrated; and certain of their anatomical characters compared with comparable-sized young of *Mugil curema* and *Mugil cephalus*.

The suggestion is made that *A. monticola* spawns at sea, with the young remaining in that habitat until they are about 20 to 35 mm. in length. This would place the species in the list of catadromous fishes.

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LARVAL FORMS OF THE FRESH-WATER MULLET (*AGONOSTOMUS MONTICOLA*) FROM THE OPEN OCEAN OFF THE BAHAMAS AND SOUTH ATLANTIC COAST OF THE UNITED STATES

By WILLIAM W. ANDERSON, *Fishery Research Biologist*

Among the Mugilidae in the dip-net collections, made during cruise 5 (Jan. 20 to Feb. 25, 1954) and cruise 9 (Nov. 3 to Dec. 12, 1954) of the Fish and Wildlife Service motorvessel *Theodore N. Gill*, were 10 larval specimens of fresh-water mullet, *Agonostomus monticola* (Bancroft). I have found no previous record of the capture of this species from the open ocean.

A. monticola is a fresh-water species of mullet. Its habitat has been given by Jordan and Evermann (1896, p. 819) as, "fresh waters of the West Indies and eastern Mexico, Vera Cruz, etc." Evermann and Marsh (1902, p. 115) record it as found in "fresh waters of the West Indies and eastern Mexico." Specific mention is made of its abundance in the fresh-water streams of Porto Rico. Meek and Hildebrand (1916, p. 335) give its habitat as "Mexico; Central America; both slopes of Panama and the West Indies"; mentioned specifically are specimens from Cuba and Guatemala. Beebe and Tee-Van (1928, p. 92) state that it is present in "fresh-water streams of the West Indies and the east coast of Mexico"; mention is made also of specimens from fresh-water streams in Haiti. Schultz (1949, pp. 111 and 112) lists the occurrence of specimens in the fresh-water rivers of Venezuela. Jordan, Evermann, and Clark (1930, p. 254) state, that this species inhabits "fresh waters of the West Indies and the Atlantic and Pacific streams of Mexico and Central America." Carr and Goin (1955, p. 84) give its habitat as small, swift streams, and its Florida range as, "streams of the Atlantic drainage and Pinellas County on the West Coast." I have located no reference to *A. monticola* occurring in streams in the Bahamas.

In addition to presenting occurrence records of the young of *A. monticola* in ocean waters off the Bahamas and the South Atlantic Coast of the United States, this report gives a description of the young, and presents the body proportions of larval and juvenile stages. It compares certain anatomical characters with the young of *Mugil curema* Cuvier and Valenciennes and with *Mugil cephalus* Linnaeus, and also discusses the possibility that *A. monticola* is a catadromous fish.

I appreciate the aid given by Giles W. Mead, Jr., and Frederick H. Berry in reviewing the manuscript. I also wish to thank Jack W. Gehringer for review of the manuscript and for other help during the course of the study. My thanks also go to officials of the United States National Museum and the Museum of the University of Florida for loan of specimens.

MATERIAL

Specimens from the *Theodore N. Gill* collections were captured at 6 locations off the Bahamas and the Florida and Georgia coasts:

Off Elbow Cay, Bahamas, 26°20′ N. and 76°44′ W., 1 specimen (28.1 mm. standard length) on Jan. 23 and 1 specimen (28.6 mm.) on Jan. 24. Off Eleuthera Island, Bahamas, 25°30′ N. and 76°30′ W., 2 specimens (24.1 mm. and 31.3 mm.) on Jan. 27, and 1 specimen (29.4 mm.) on Jan. 28. Off lower Florida coast, 28°00′ N. and 79°00′ W., 1 specimen (25.5 mm.) on November 16. Off central Florida coast, 29°00′ N. and 80°32′ W., 1 specimen (30.6 mm.) on Nov. 17. Off central Florida coast, 29°00′ N. and 79°48′ W., 2 specimens (26.4 and 27.0 mm.) on Nov. 18. Off the lower Georgia coast, 30°57′ N. and 79°14′ W., 1 specimen (27.3 mm.) on Nov. 19. See figure 1.

For comparison, I examined 2 specimens of *A. monticola* (33.0 and 39.0 mm. standard length) U. S. National Museum No. 101483, taken in Rio Carolina, Porto Rico, Feb. 17, 1934; and from the University of Florida collections, 7 specimens (31.5, 47.0, 55.9, 59.0, 64.5, 75.5, and 119.0 mm.) taken approximately 2 to 4 miles upstream from the mouth of the Yateras River, Cuba, on Sept. 16, 1952; also from the University of Florida collections taken from fresh waters of Florida, 3 specimens (44.8, 48.0, and 56.0 mm.) from Cedar-

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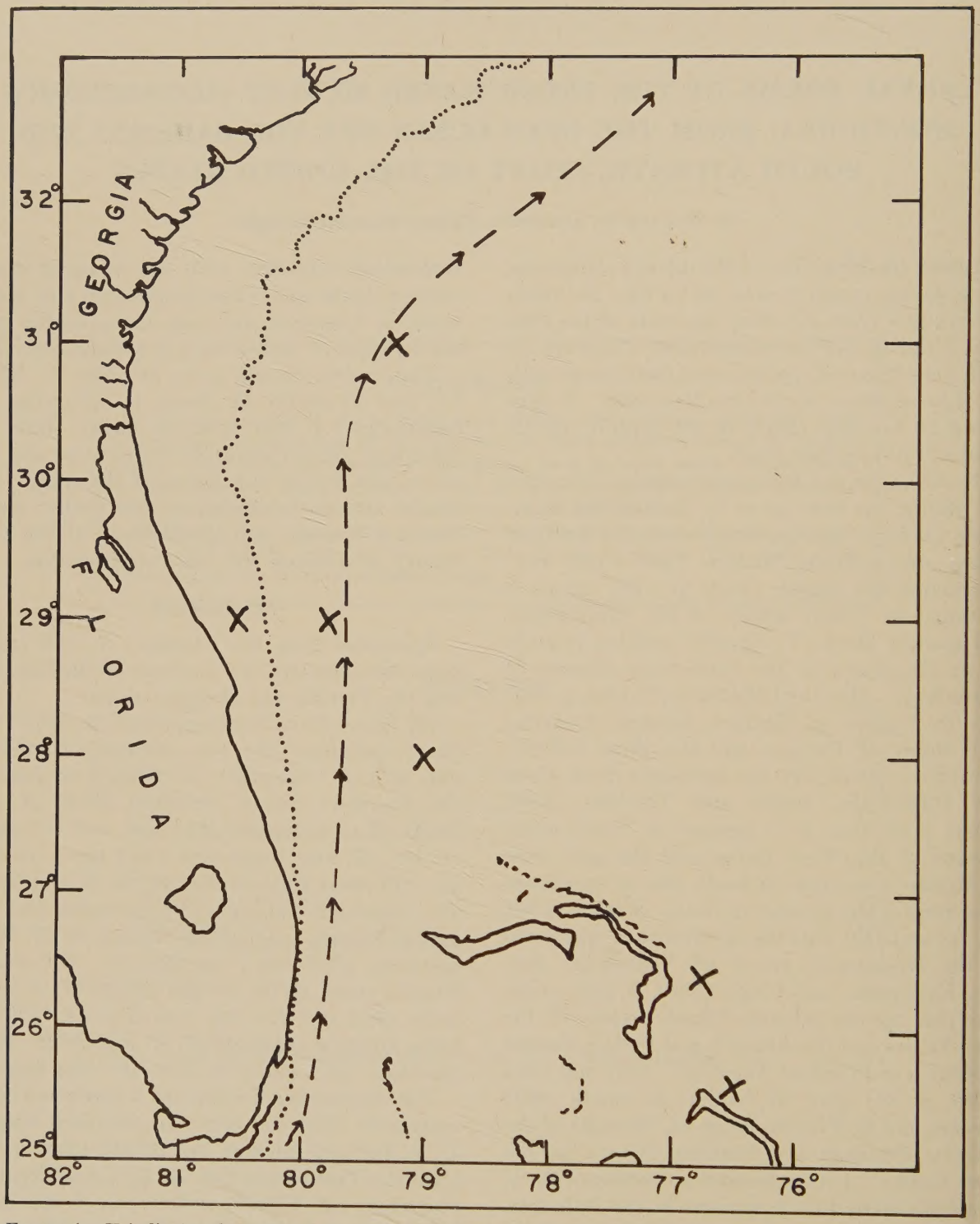

FIGURE 1.—X indicates the areas of capture of the fresh-water mullet, *Agonostomus monticola*. Arrows on dashed line show approximate axis of Gulf Stream. Dotted line represents the 20-fathom curve.

Cow Creek ¼ mile east of Samsula Junction on Florida Highway 75, Volusia Co., captured Feb. 21, 1948; 1 specimen (32.4 mm.) from Volusia Co., taken in 1948; 1 specimen (81.5 mm.) from Cedar-Cow Creek, Volusia Co., taken in June 1949; 3 specimens (66.1, 68.0, and 75.5 mm.) from Cow Creek, Volusia Co., taken on May 23, 1949; 4 specimens (94.4, 96.5, 105.0, and 105.3 mm.) from an artificial fresh-water pond near St. Augustine Beach, St. Johns Co., taken August 30, 1949; 2 specimens (62.0 and 63.8 mm.) from Spruce Creek, Volusia Co., taken April 29, 1950; and 1 specimen (26.7 mm.) from Spruce Creek, Volusia Co., taken Nov. 8, 1951.

METHODS

Methods employed aboard the vessel *Theodore N. Gill* are given by Anderson, Gehringer, and Cohen (1956).

Descriptions are based on preserved material, and measurements of larvae up to about 35 mm. standard length were made with a stereoscopic microscope and a micrometer eyepiece. The larger specimens were measured with calipers. Original measurements were used in constructing the graphs to portray rates of growth of various body parts, and changes in body proportions.

DESCRIPTION

In general appearance these sea-stage young of *A. monticola* closely resemble the sea-stage young of both *M. curema* and *M. cephalus*, the most striking difference being that *A. monticola* appears much more slender and with a longer caudal peduncle. All are heavily pigmented and appear blackish. Figure 2 illustrates a 31.3-mm. specimen. Observed under magnification, the presence of ctenoid scales quickly separates *A. monticola* from these two species of *Mugil*.

FINS

Dorsal:—All except two of the 34 specimens examined had a dorsal fin formula of IV–I, 8. One of the Florida specimens (96.5 mm.) had 5 spines in the first dorsal, arranged in a peculiar manner so as to appear as two fins; the 1st, 2d, and 3d spines were connected by membranes, the 3d and 4th spines were not connected by a membrane, but the 4th and 5th spines and the 5th spine and the body were connected by membranes (this appears to have resulted from an abnormal division of the 3d spine, although all spines were of normal size). One specimen from Cuba (64.5 mm.) had only 6 soft rays instead of the usual 8.

Anal:—All except one of the specimens examined had an anal fin formula of II, 10 (one Florida specimen, 81.5 mm. had II, 9). In figure 3 the details of the anal fin of cleared and stained specimens of *A. monticola*, *M. curema*, and *M. cephalus* at comparable sizes (about 30 mm.) are illustrated. Both spines and the first soft ray in *A. monticola* are shorter and more slender than in *M. curema* and *M. cephalus*. A notable difference at this size occurs in the last ray. In both *M. curema* and *M. cephalus* this ray has two main branches, each of which is in turn deeply forked, while in *A. monticola* only the anterior main branch is forked.

A difference in the number of anal spines reported for *A. monticola* occurs in the literature. Jordan and Evermann (1896) on page 809 in their key to the genera of Mugilidae indicate 2 anal spines for *Agonostomus* Bennett; on page 818 under the generic description is the statement, "Anal spines usually 2, the first soft ray slender and often taken for a spine"; pages 819 and 820 describe 4 species of *Agonostomus*, including *A. monticola*, each of which is given an anal fin formula of III, 9. Evermann and Marsh (1902)

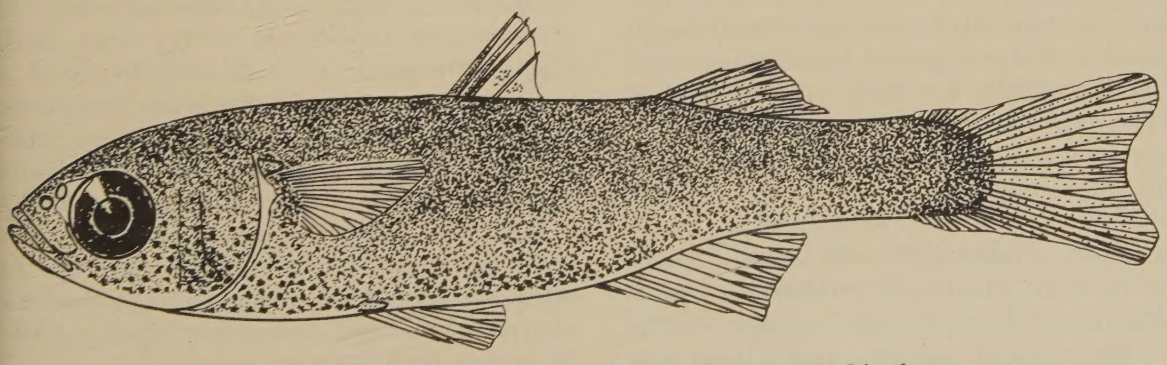

FIGURE 2.—A young *Agonostomus monticola*, 31.3 mm. long, captured in the open ocean.

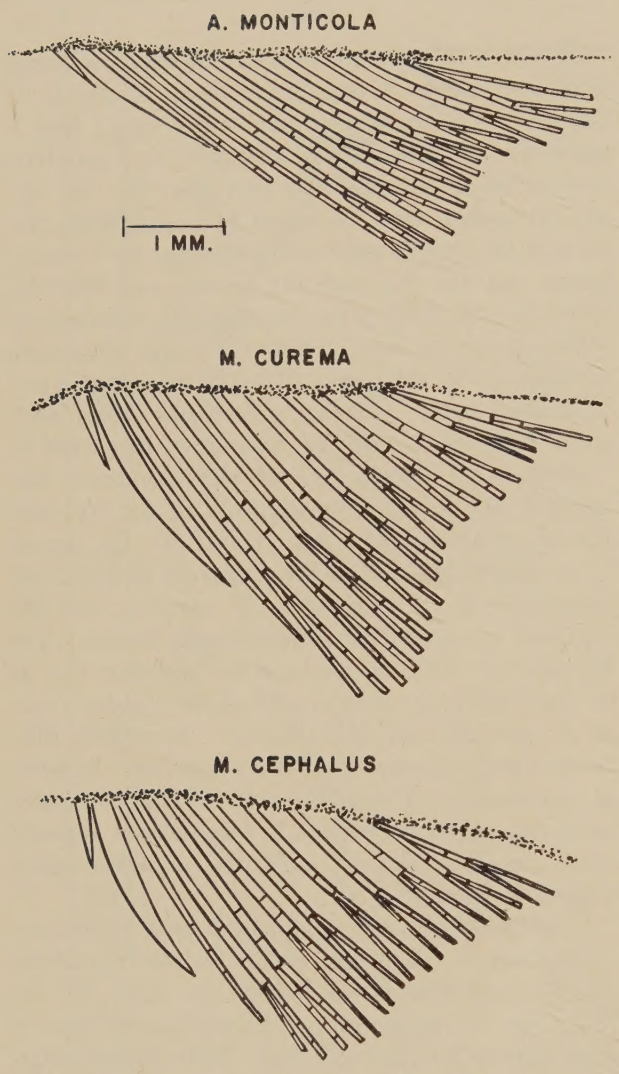

FIGURE 3.—Anal fins from a 29.4-mm. specimen of *Agonostomus monticola*, a 30-mm. *Mugil curema*, and a 30-mm. *Mugil cephalus*. (Camera lucida drawings from cleared and stained specimens.)

on page 112 in their key to the Mugilidae give 2 anal spines for *Agonostomus*, on page 114 under the generic description "Anal spines usually 2, first soft ray slender and often taken for a spine"; Evermann and Marsh give *A. monticola* an anal fin formula of III, 9. Meek and Hildebrand (1916) on page 333 under the generic description of *Agonostomus* state, "anal spines 2, the first one minute, often hidden in the skin"; and on page 334, they show an anal fin formula of II, 10 for *A. monticola*. Hubbs (1944) on page 72, in his discussion of the anal fins of various fish, reports that Mugilidae, "Instead of having only one thin flexible anal spine all mugilids have 2 thick pungent anal spines, and the third ray with age tran forms (in the Mugilinae but not in the Agono tominae) from a flexible, paired, articulated so ray into a pungent, solid, unsegmented spi (Jacot, 1920:207–208)." Schultz (1949, p. 11 gives an anal fin count of III, 9 for specimens *A. monticola* from Venezuela. Carr and Go (1955, p. 83) give an anal fin count of III, 9 f specimens from Florida.

The 34 specimens I have examined (rangi from about 24 to 119 mm. standard length) ha only two anal spines. The third ray, even in t largest specimens, shows no evidence of tra forming into a solid unsegmented spine; the se ments in this slender ray are difficult to see unl examined under magnification.

Pectoral:—Of the 34 specimens examined, had 14 rays, 26 had 15 rays, and 5 had 16 ra Placement, shape, and extension of this fin a illustrated in figure 2.

Caudal:—The caudal skeleton of a cleared a stained specimen (29.4 mm. standard length) illustrated in figure 4. There are 14 princip rays of which 12 branched; and 19 secondary ra 9 dorsal and 10 ventral. Of interest, at this size the peculiar branching of the 8 middle princip rays, which end in three tips (as do the last dor and anal fin rays). In *M. curema and M. cepha lus* at comparable size, the 8 middle caudal ra and the last dorsal and anal rays end in 4 tips

PREMAXILLARY, MAXILLARY, AND PREORBIT BONES

Schultz (1946) in his revision of the genera the family Mugilidae pointed out the importa of these bones in separation of the various gene In figure 5 are illustrated these bones from clea and stained specimens: a 29.4-mm. *A. montic* and 30-mm. *M. curema* and *M. cephalus*. T great similarity of these bones in the two memb of *Mugil* is striking, as are their differences fr *A. monticola* (which has a very wide, serra posterior margin; tips of maxillary and p maxillary extending farther below the poster margin of preorbital; a deep hook about midw on the rear edge of premaxillary; and entir different shape of tips of maxillary and p maxillary). In some larger specimens of *monticola* there are serrations along the fr edge of the preorbital in addition to those alo the posterior edge (serrations on the poster edge vary from about 9 to 13).

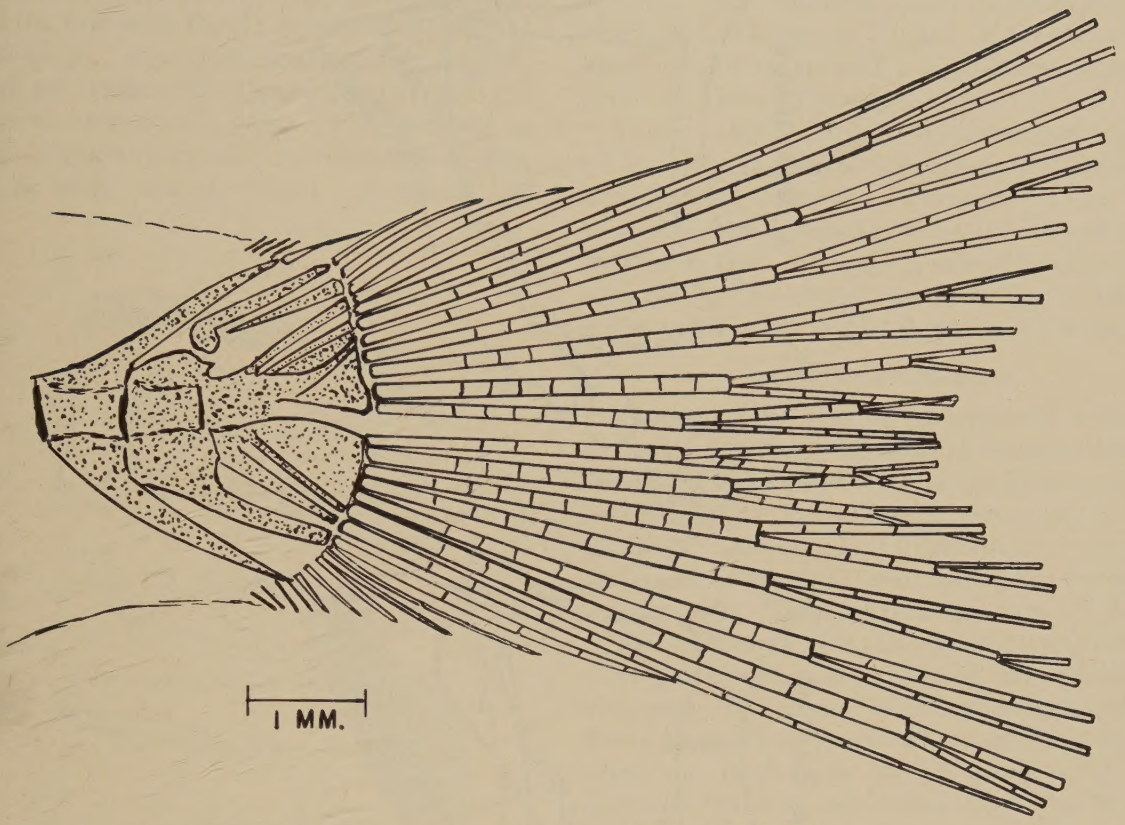

FIGURE 4.—Caudal skeleton of a 29.4-mm. *Agonostomus monticola*. (Camera lucida drawing from a cleared and stained specimen.)

TEETH

The larval sea-stage of *A. monticola* have a band of strong, sharp-pointed, conical-shaped teeth in the upper and lower jaws, of which the outer ones are the larger (fig. 6A and 6B); bands of sharp-pointed, conical-shaped teeth on the vomer and palatines (fig. 6C); and strong, sharp-pointed conical teeth on the tongue arranged in several patches; one center patch near the tip of the tongue, followed by a single row of about 8 to 10 teeth along each side of the tongue, and a small isolated center patch of smaller teeth near the rear of the tongue (fig. 6D). There are no teeth in the lips of *A. monticola*.

In *M. curema* and *M. cephalus* there are no teeth on the vomer or palatines, and the setiform or ciliform teeth occur in the upper and lower lips.

PIGMENTATION

The sea-stage specimens of *A. monticola* are all rather heavily pigmented (some more than others) so that they appear black on the upper half of the body shading to a lighter, yellowish color on the ventral surface. Pigment spots are smaller and closer together on the upper part of the body and larger and less numerous on the lower half of the body. In the size range of sea-stage specimens (24.1 to 31.3 mm.) the first and second dorsal fins and the caudal fin have pigmentation, but the anal, pectorals, and ventrals do not. See figure 2.

This is in sharp contrast to the coloration of specimens examined from fresh-water streams. These tend to be brownish on the dorsal surface, becoming blotched brownish to below the midline of the body, and white on the belly and the lower sides of the body and head. There is a dark spot at the caudal base.

MISCELLANEOUS STRUCTURES

Gill rakers.—The following counts were obtained on the lower limb of the first arch: 14 in a 25.5 mm. specimen; 16 in specimens 29.4 and 31.5 mm.; 17 in a 39-mm. specimen; and 19 in

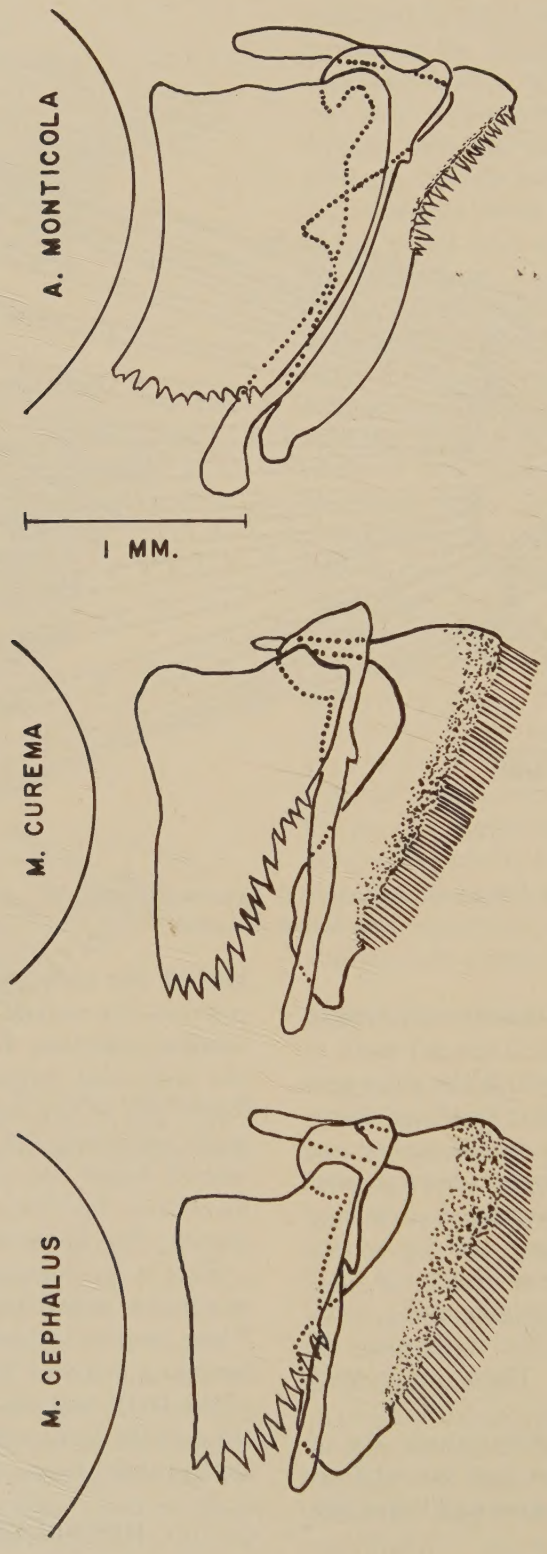

FIGURE 5.—Premaxillary, maxillary, and preorbital bones in a 29.4-mm. *Agonostomus monticola*, a 30-mm. *Mugil curema*, and a 30-mm. *Mugil cephalus*. (Camera lucida drawings from cleared and stained specimens.)

specimens of 68 and 105 mm. Meek and Hildebrand (1916, p. 334) give gill rakers on the lower limb of the first arch for *A. monticola* as ranging from 17 to 20. It appears that the full complement of gill rakers develops when the fish are between 30 and 40 mm. long. This increase in number of gill rakers with increase in size also occurs in other related species. A 30-mm. *M. curema* had 30 gill rakers on the lower limb of the first arch whereas adults have more than twice that number; a 30-mm. *M. cephalus* had about 25 gill rakers and a 60-mm. specimen had about 40 (lower limb first arch).

Scales:—All specimens examined had ctenoid scales. Figure 7 shows arrangement of spines on a scale from a 28.6-mm. specimen. There were 39 to 42 (most frequently 40 or 41) rows of scales in a series from the upper angle of the opercle to the middle of the caudal base; and 11 or 12 rows of scales between the second dorsal and the anal fin.

BODY PROPORTIONS

Measurements from the 34 specimens examined (ranging from 24.1 to 119 mm., standard length) were used to estimate the relation between standard length and eye diameter, head length, body depth (at pectoral), and distances from snout to insertions of the first dorsal fin, second dorsal fin, and anal fin. These relationships are illustrated in figures 8 and 9, and the rate of development of body parts, within the range of sizes studied, is apparent. The upward shift in the regression line for body depth (at pectoral) occurs between sea-stage and fresh-water stream material. I have observed the same occurrence in *M. curema* be-

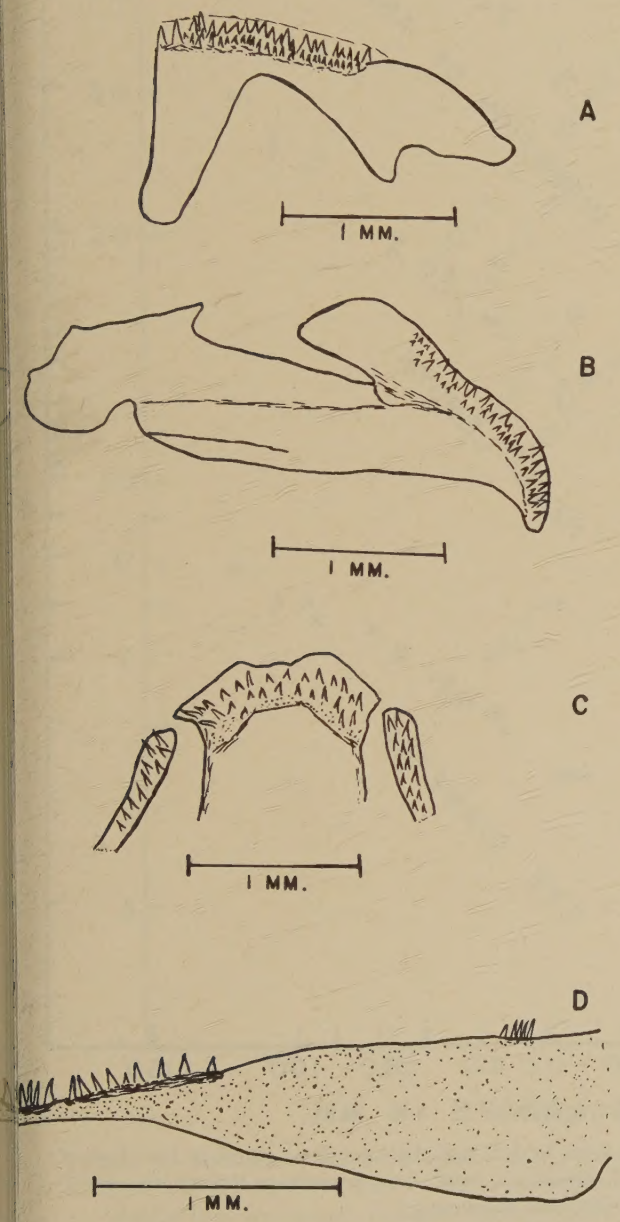

FIGURE 6.—Arrangement and form of teeth in a 29.4-mm. *Agonostomus monticola:* A, left half of premaxilary; B, left half of lower jaw; C, vomer and palatine bones; D, tongue. (Camera lucida drawings from a cleared and stained specimen.)

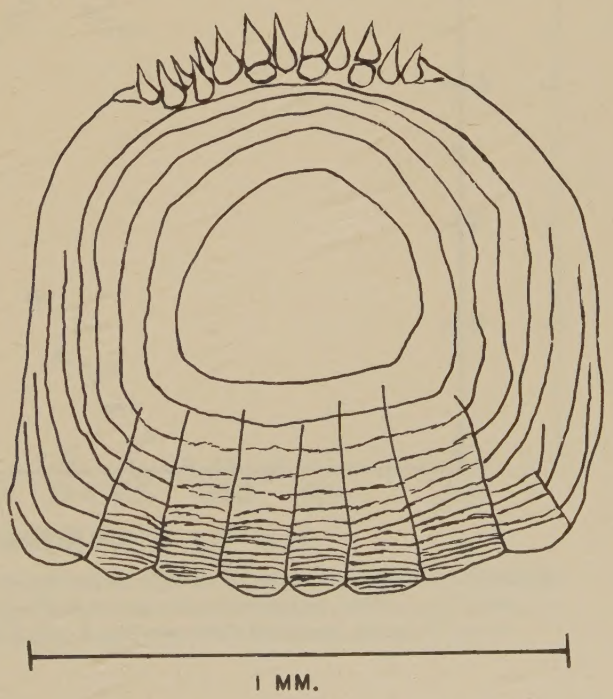

FIGURE 7.—Scale from a 28.6-mm *Agonostomus monticola*, showing arrangement of spines. (Scale taken above midline of body between second dorsal and anal fins.)

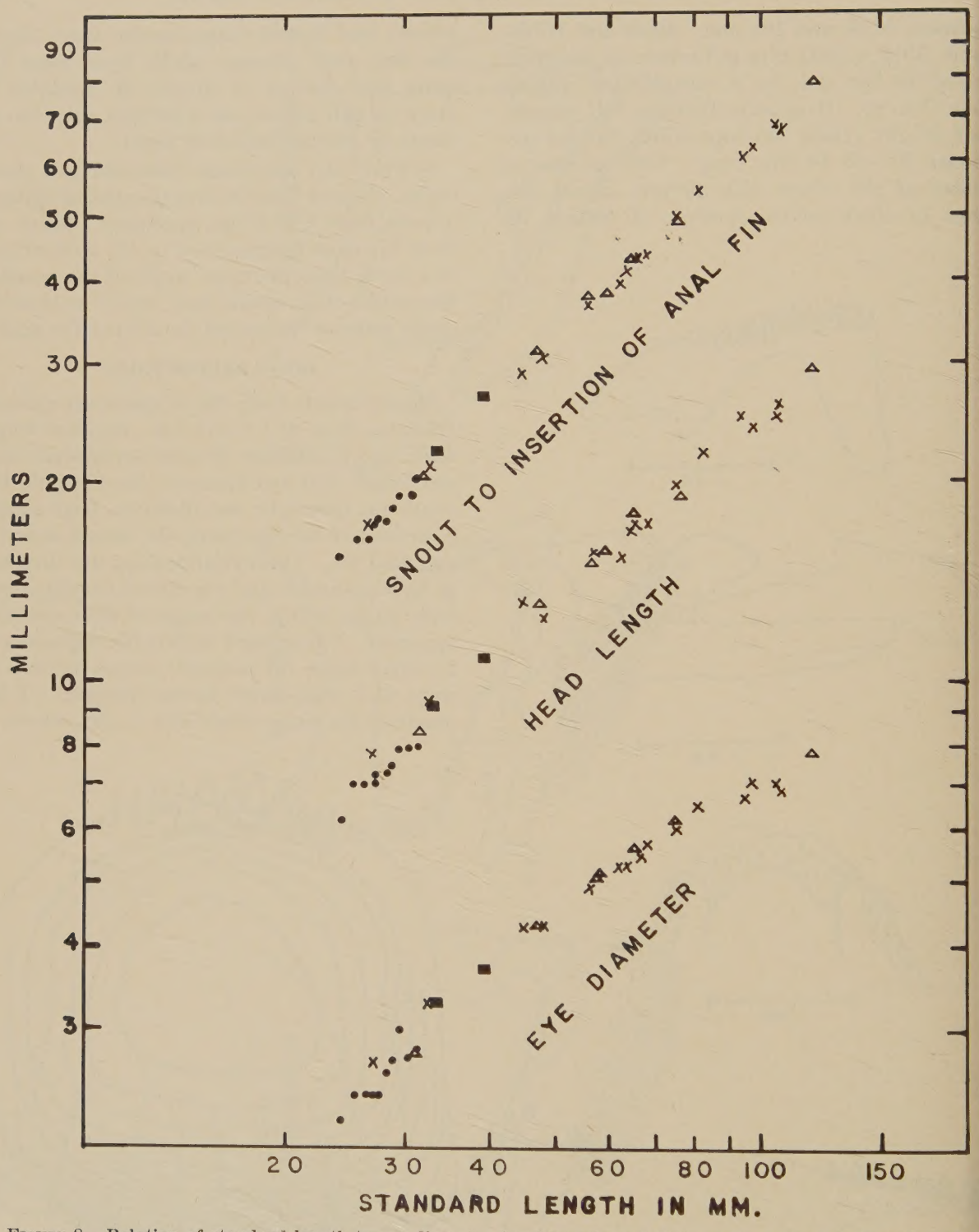

FIGURE 8.—Relation of standard length to eye diameter, head length, and distance from snout to insertion of anal fin. (Dots represent sea-stage larvae from *Gill* collections, solid squares indicate Puerto Rico specimens, triangles represent Cuba specimens, and X's the Florida specimens.)

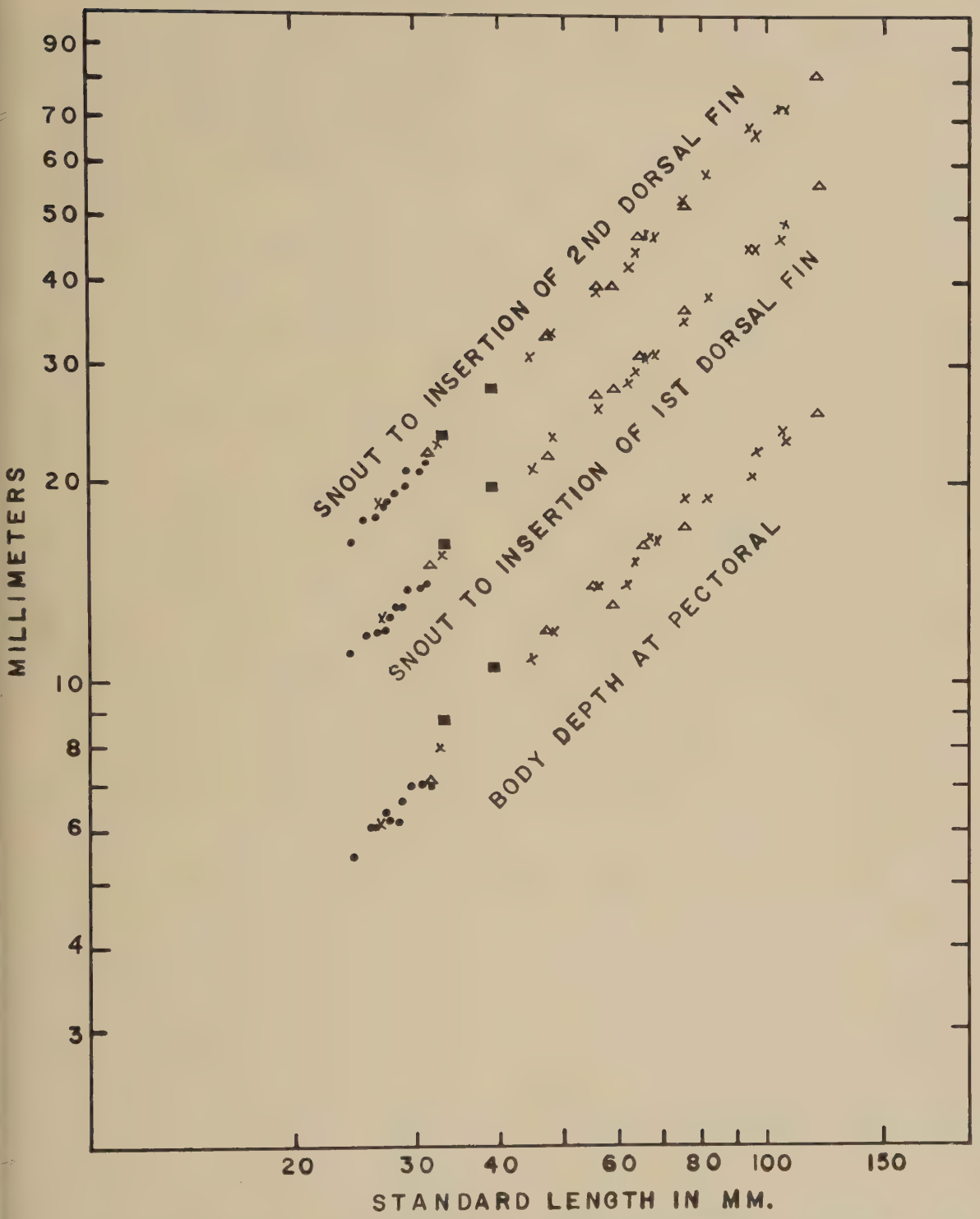

FIGURE 9.—Relation of standard length to body depth (at pectoral), and distance from snout to insertions of first and second dorsal fins. (Dots represent sea-stage larvae from *Gill* collections, solid squares indicate Puerto Rico specimens, triangles represent Cuba specimens, and X's the Florida specimens.)

tween the sea-stage and inshore specimens, and attribute it to a greater abundance of food in the inshore areas, which is reflected in a pot bellied appearance (Anderson 1957).

OCCURRENCE OF LARVAL AND JUVENILE FORMS

The literature presents interesting facts regarding sizes of *A. monticola* obtained from fresh-water streams. Evermann and Marsh (1902, p. 115) say, "It is very abundant in the fresh-water streams of Porto Rico, and is much used as food; many were collected at Caguas in the Rio Loiza and Rio Caguitas and in Rio Bayamon at Bayamon, of all stages of growth from 1.5 to 11 inches" (minimum size taken, 1.5 inches, is about 38 mm.). Meek and Hildebrand (1916, p. 335) had 118 specimens in their collection from Panama which ranged from 40 to 255 mm.; taken from lowland streams, some from brackish water, and a few from upland streams. Beebe and Tee-Van (1928, p. 92) found the species in sea-ward flowing streams of the Cul-de-Sac Plain at Source Mariani in Haiti; they had 49 specimens ranging from 43 to 188 mm. Schultz (1949, pp. 111 and 112) lists collections from several rivers in Venezuela, and the smallest specimen listed was 22 mm. A series of specimens in the University of Florida collections from the Yateras River, Cuba, ranged from 31.5 to 119.0 mm. The University of Florida's collection from streams in Florida contains specimens ranging from 26.7 to 105.3 mm.

From these records it appears that about 22 mm. is the smallest size at which this species has been taken from fresh-water rivers; a strange occurrence if the species spawned and developed in fresh water. The specimens taken by the *Gill* in ocean waters off the Bahamas, Florida, and lower Georgia coasts (ranging in size from 24.1 to 31.3 mm.) assume greater significance in view of this, and very strongly point to a sea spawning for *A. monticola*, with the young remaining at sea until they have reached a size of about 20 to 35 mm. This would make the species a truly catadromous fish.

I have located only one reference in support of placing *A. monticola* in the list of catadromous fishes, and this reference refers only to the genus and not to a particular species, although I suspect that *A. monticola* is involved. Myers (1949, p. 94) in his discussion of terms for migratory fishes states that "The mullet, *Agonostomus*, may perhaps be added to the small known list of truly catadromous fishes. Dr. C. L. Hubbs tells the writer that he has found the 'Querimana' stage of this genus 'in completely salt water in Acapulco Bay,' Mexico, but it is, of course, possible that *Agonostomus* may belong in the next division." (The next division referred to is "Amphidromous," defined by Myers as, "Diadromous fishes whose migration from fresh water to the sea, or vice versa, is not for the purpose of breeding, but occurs regularly at some other definite stage of the life-cycle.")

SPAWNING

Placing the time of spawning of the larval specimens taken off the Bahamas, Florida, and lower Georgia coasts must be based on two things, one factual and one an assumption. Specimens 24.1 to 31.3 mm. were taken during late January 1954 and specimens 25.5 to 30.6 mm. were taken in mid-November 1954. Assuming a period of 4 to 6 weeks for the larvae to attain a length of 20 mm. after hatching, the *Gill* specimens would have been spawned from September to December.

I believe that the larval specimens taken by the *Theodore N. Gill* probably were spawned much farther south and the larvae were carried northward by the prevailing currents. This would partially explain our failure to capture smaller specimens. Also, I suspect that the occurrence of the species in Florida streams has resulted from "seeding" by specimens carried northward by the Gulf Stream from possible spawning off the Cuban coast. The largest specimen in the University of Florida collection (from Florida) is 105 mm., and it is not known whether or not the species is maturing in waters of that State. The collection of specimens from St. Augustine Beach, Fla., is the most northward recorded occurrence in fresh waters on the Atlantic coast.

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